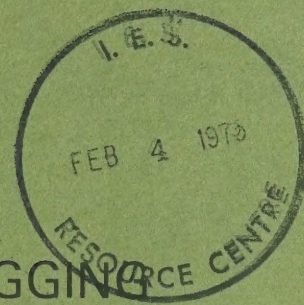


Canada, Forestry Service (FS).

Information Report PS-X-46

EARLY EFFECTS OF BURNING AND LOGGING IN PINE-MIXEDWOODS.

1. FREQUENCY AND BIOMASS OF MINOR VEGETATION. / Sidhu,
S.S. 1973.

EARLY EFFECTS OF BURNING AND LOGGING IN PINE-MIXEDWOODS

1. Frequency and Biomass of Minor Vegetation

by S.S. Sidhu

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PETAWAWA FOREST EXPERIMENT STATION
CHALK RIVER, ONTARIO
INFORMATION REPORT PS-X-46
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1. Frequency and Biomass of Minor Vegetation

by

S.S. Sidhu

Petawawa Forest Experiment Station

Chalk River, Ontario

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ABSTRACT

This report describes the early quantitative changes in frequency and biomass of minor plant species following partial logging and prescribed burning in pine-mixedwoods. A procedure for estimating changes in single species is proposed for forest situations where treated and control plots are not exact replicas of each other. The procedure works well for species of moderate to high abundance and gives unreliable estimates of change for less common species.

Several species in the shrub stratum (Abies, Acer, Kalmia, Vaccinium) can be temporarily eliminated by prescribed fires. Hazel (Corylus cornuta) can be partially controlled by one light fire. Betula and Populus are favoured by one light fire.

There is an increase in number of species of minor vegetation following logging, however the change in the number of species is not significant after burning.

Following both logging and burning, there is a definite change in species composition and abundance. Seasonal changes in logged stands are of smaller magnitudes compared with the changes in unlogged-unburned stands.

Total biomass of minor vegetation increased after logging and decreased after burning. Seasonally, there was little change in biomass in undisturbed stands, but biomass increased substantially from spring to summer in logged-unburned stands.

The species are grouped in five response-categories. There was no apparent relationship between the reproductive biology of the species and their response category. However, species reproducing by seeds viz. Geranium, Convolvulus, Polygonum, Prunus become important after burning.

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EARLY EFFECTS OF BURNING AND LOGGING IN PINE-MIXEDWOODS

1. Frequency and Biomass of Minor Vegetation

by

S.S. Sidhu^{1/}

INTRODUCTION

This report is the first in a series, and deals with the quantitative changes in frequency and biomass of minor plant species following partial logging and prescribed burning. The data in this report pertain to herbs and up to three meters high semi-shrubs, shrubs and tree seedlings. The early effects of logging and burning on the growth of remaining trees are not early detected in the first year following treatments. The herbs and shrubs, however, are affected drastically, and undergo their most important changes during the first year.

Sufficient knowledge of the effects of fire and logging on pine regeneration, plant succession and species diversity in pine mixedwoods is still lacking, particularly where fire treatments are applied in standing timber. Before prescribed fires become an accepted forestry practice to control undergrowth and promote pine regeneration, more information is needed to answer questions from the forest managers and the public at large. The questions have to do with the magnitude and duration of the effects of fire and logging on:

- a) pine regeneration
- b) growth of remaining trees
- c) shrubs and herbs
- d) future stand composition
- e) soil water
- f) soil nutrients

^{1/} National Research Council Postdoctoral Fellow, Petawawa F.E.S., Chalk River, Ontario. Presently, Ecologist, Nfld. Forest Research Centre, St. John's, Nfld.

g) birds and mammals

h) aesthetic factors

This report gives a partial answer to question (c), in particular how the frequency of occurrence, biomass and relative importance of the various shrub and herb species changed during the first year following logging and fire treatments.

BACKGROUND INFORMATION

Many of the present white and red pine stands are located in the Great Lakes - St. Lawrence and Acadian Forest Regions of Canada (Halliday 1937, Rowe 1959). Horton and Bedell (1960) described these stands as edaphic and pyric climaxes and considered the existing climatic conditions to be unsuitable for the self-perpetuation of pines in the present pine-mixedwoods.

It appears from the available literature that partial shade, light ground-vegetation, and some exposed mineral soil promote good seed germination and seedling growth in red and white pines (Shirley 1933, Smith 1940, Horton and Bedell 1960). These conditions in natural stands are created following fire or local disturbances such as windfall, erosion, etc. (Nichols 1935, Maissurow 1935, Spurr 1953). Under experimental conditions, Van Wagner (1963, 1970) reported successful regeneration of red and white pine following light experimental fires. Such information indicates that a successful regeneration of pines in the pine-mixedwoods will, in many cases, require temporary removal or reduction of the undergrowth by fire or alternate methods (brush-cutting, spraying with herbicides, scarification, etc.). Of the available means of controlling undergrowth, fire is a favoured choice because a) the plant and animal species in these forests have been exposed to fires over the past, b) fire has been a key factor in the perpetuation of pine-mixedwoods, c) cutting costs are high, and d) the use of herbicides is not favoured by the public at large.

DESCRIPTION OF THE STUDY AREA

LOCATION AND DESCRIPTION

The study area was located in the Cartier Lake basin in the Petawawa Forest Experiment Station, near Chalk River, Ontario (Fig. 1). The area formed a part of the 'Stand 102' of Brace's study^{2/}, classified as a two-storied pine-mixedwood. Pre-cut and post-cut stand compositions are given in Table 1. The stand treatments, slope and stand area are presented in Table 2. The logging in these stands was aimed mainly

^{2/}Brace, L.G. 1972. Assessing silvicultural stand improvement alternatives in pine-mixedwoods. 1. Costs and effects of cutting treatments. Internal Rep. PS-27, Petawawa Forest Experiment Station, Chalk River, Ontario.

Fig. 1. Study Area, Stand 102A, B, C, D and E were included in this study.

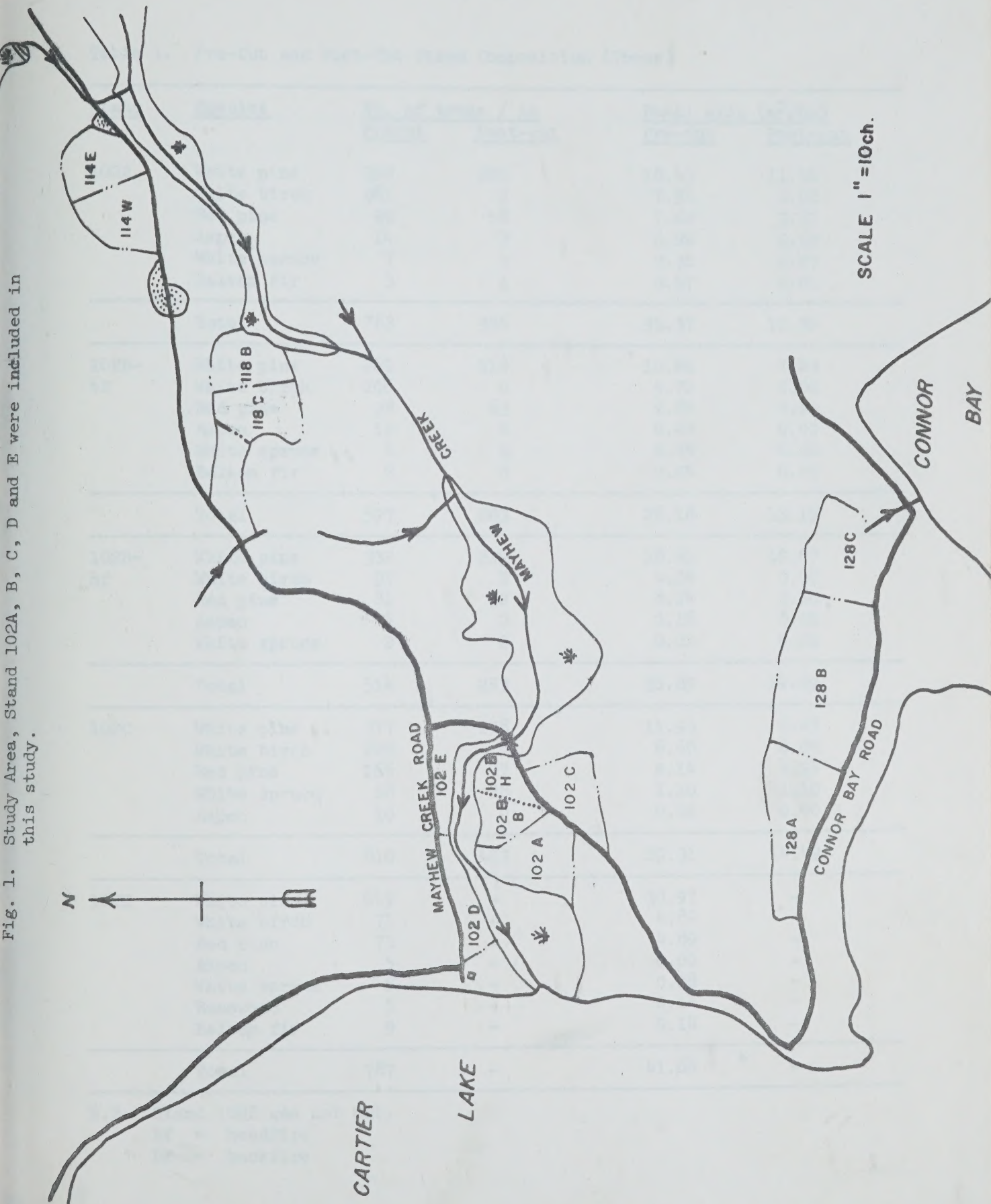


Table 1. Pre-Cut And Post-Cut Stand Composition (Trees)

Stand	Species	No. of trees / ha		Basal area (m ² /ha)	
		Precut	Post-cut	Pre-cut	Post-cut
102A	White pine	399	292	18.43	11.50
	White birch	261	2	7.94	0.02
	Red pine	99	58	7.62	3.72
	Aspen	14	0	0.99	0.00
	White spruce	7	3	0.32	0.07
	Balsam fir	3	1	0.07	0.01
Total		783	356	35.37	15.32
102B- bf	White pine	269	218	10.60	7.23
	White birch	206	0	5.72	0.00
	Red pine	98	63	8.82	5.90
	Aspen	18	0	0.94	0.00
	White spruce	4	2	0.05	0.02
	Balsam fir	2	0	0.05	0.00
Total		597	283	26.18	13.15
102B- hf	White pine	332	219	18.41	10.67
	White birch	95	0	4.04	0.00
	Red pine	81	32	8.24	3.60
	Aspen	4	0	0.18	0.00
	White spruce	2	2	0.02	0.02
Total		514	253	30.89	14.29
102C	White pine	377	298	11.93	8.45
	White birch	229	0	6.68	0.00
	Red pine	166	97	9.14	4.94
	White spruce	28	28	1.10	1.10
	Aspen	10	0	0.46	0.00
Total		810	423	29.31	14.49
102E	White pine	619	-	30.97	-
	White birch	71	-	4.82	-
	Red pine	73	-	4.89	-
	Aspen	5	-	0.60	-
	White spruce	5	-	0.28	-
	Basswood	5	-	0.14	-
	Balsam fir	9	-	0.14	-
Total		787	-	41.84	-

N.B. Stand 102E was not cut.

hf = headfire

bf = backfire

Table 2. Stand Treatments, Slopes And Stand-Areas

Stand	Treatment	Slope		Area (Hectares)
		Degrees	Aspect	
102A	Logged, headfire	7 - 12	SW, SSW, W, WNW	1.98
102B-bf*	" "	9	ENE, ESE, SE	0.57
102B-hf**	Logged, backfire	12 - 15	S, SE	0.53
102C	Logged, unburned	0 - 7	N, NE	0.65
102E	Unlogged, unburned	-	-	0.57

* backfire

** headfire

at increasing sawlog yield of pines. About 50% of the total volume was logged in December, 1971. The operation is described by Brace.^{2/} After logging the stands were mostly composed of red and white pine with insignificant volumes of white spruce and minor hardwoods (Table 1). Most of the pines were 10-25 cm in diameter and 60-80 years old.

SOILS, GEOLOGY AND CLIMATE

The soils in the study area vary from coarse gravelly sand to loamy sand. According to Gadd (1962), these soils have resulted from glacio-fluvial deposits of fine-grain grey sand with pockets of silt to surface-lying fluvial gravel. The whole area is a heterogeneous matrix of the above mentioned components.

Gillespie et al. (1964) classified the soils of Cartier Lake as Monteagle-Rock (Msl-R) composed of sandy loam, rock outcrop, peat, muck, etc. In the study area soils are well drained and topography is flat to gently rolling.

The climate of the area has been described in the Program Review of the Petawawa Forest Experiment Station, Chalk River, Ontario (Anon 1969). Brace^{2/} described the history and use of forest in this area.

METHODS

The field and laboratory methods which are common to this and subsequent reports are described only in this report. The methods specific to a report will be given in that individual report separately. Gleason (1952) was followed for nomenclature of all plant species.

FIELD METHODS

Burning

Stands 102A, 102B-bf (backfire) and 102B-hf (headfire) were burnt under the supervision of C.E. Van Wagner, F.F.E.S., Chalk River, Ontario. The description of fires in these stands is summarized in Table 3.

Vegetation Sampling

Field methods for sampling vegetation were designed to collect information to evaluate

- a) changes in abundance and biomass of individual species following logging and burning,
- b) changes in stand composition and diversity before and after treatment, and
- c) the rate of vegetation recovery in the herb, shrub and tree strata.

Table 3. Fire Description For Various Stands^{1/}

Parameter	Stands		
	102A-hf	102B-bf*	102B-hf**
Date of fire	July 17/72	July 6/72	July 6/72
Fire Weather Index	6	16	16
Rate of spread (ft/min)	1-15	1.25	18
Duff consumed (lbs/ft ²)	0.139	0.252	0.221
Brush consumed (lbs/ft ²)	0.007	0.007	0.010
Slash consumed (lbs/ft ²)	0.438	0.438	0.438
Total wt. consumed (lbs/ft ²)	0.589	0.697	0.669
Heat of combustion	8,000	8,000	8,000
Fire Intensity (BTU/sec/ft)	80-1200	110	1,600
Soil exposure	Very little	Very little	Very little
Tree damage (% of trees with 90% crown scorch)	12	8	80

^{1/}Table 3 compiled from unpublished data (C.E. Van Wagner)

*bf = backfire

**hf = headfire

I. Tree Sampling

Complete inventory of trees in each of the stands was taken and a summary of stand tables prepared (Table 1).

II. Shrub Sampling

All semishrubs, shrubs and tree seedlings from 30 to 270 cm in height were included in the shrub sample. Twenty-four circular plots (1 m radius) were sampled in each of the stands. Due to various limitations, the data on the shrub survey can be used only to evaluate the gross changes in shrub undergrowth due to logging and burning.

III. Sampling Of Herbs, Semishrubs, And Tree Seedlings

All herbaceous species, semishrubs and up to 100 cm tall shrubs and tree seedlings were included in this sample. The species in this category were sampled for percent frequency of occurrence as well as biomass of above ground parts.

The presence and absence of species when expressed as percent frequency of occurrence is important in terms of spatial diversity and aesthetics. However, it tends to give equal weights to individuals of different sizes and different numbers of individuals in various sample plots. In reality a single large individual of one species may have a similar or greater impact than a large number of small individuals on the same 'living space' in the forest community. Therefore, it is important to study both the spatial dispersion of individuals as well as the biomass of plant species in a forest community.

The forest vegetation in the shrub and herbaceous strata changes significantly from spring to fall and plant species of these strata fall broadly into two phenological categories; a) species that flower in spring, and b) species that flower in late summer. In order to have a better representation of a large number of species in samples, each stand was sampled once in June and then in August, 1972.

The methods of sampling for % frequency of occurrence and biomass are described in the following sections:

a) Presence and absence

The presence of herbaceous species and semishrubs, shrub and tree seedlings up to 100 cm in height was recorded in twenty 0.5 m x 0.5 m quadrats in each stand at each time of sampling. The first quadrat was positioned randomly in a stand and the subsequent quadrats were placed regularly along transects distributed uniformly over the stand-area. Twenty quadrats were an adequate sample determined by species - area curves.

b) Biomass:

The above ground portions of all species occurring in 0.5 m x 0.5 m quadrats were clipped, put in brown paper bags, and brought to the laboratory for sorting and drying. Twenty such quadrats were sampled in each of the stands at each time of sampling.

The contents of each of the 20 quadrats clipped in each stand were sorted by species and their presence confirmed in the presence list prepared in the field. The contents from 20 quadrats were lumped together by species and dried in hot-air ovens at 80°C for 24 hours. From the ovens the materials were transferred to large desiccators with CaO₂. After the materials had cooled to room temperature, the weight of dry matter (biomass) of each species was determined.

In sampling the herbaceous stratum, local areas where there was a pronounced evidence of disturbance due to skidding, piling and trampling were not included in the sample.

The border areas (about 7 to 15m wide band) were also excluded from sample to minimize effects of roads and fire guards.

STATISTICAL PROCEDURES

Percent Frequency, % Relative Frequency and Relative Biomass

The presence of species was expressed as:

$$\% \text{ Frequency} = \frac{\text{No. of quadrats in which a species occurred}}{\text{Total No. of quadrats sampled in a stand}} \times 100$$

$$\% \text{ Relative Frequency} = \frac{\text{Frequency of sp. (A)}}{\text{Sum frequencies of all species present}} \times 100$$

Similarly biomass (dry matter) of each species present was determined in twenty 0.5 m x 0.5 m quadrats (total 5 m²) for a stand and relative biomass for each species was determined by the equation.

$$\text{Relative Biomass} = \frac{\text{Biomass of Sp. (A)} \times 100}{\text{Sum biomass of all species present}}$$

Quantitative Measure Of Change In Single Species

In forest communities, assumed to be relatively stable, two kinds of changes can be expected following treatment such as logging and burning; a) Change associated with time (i.e. with progression of season or years from the time of treatment) and b) Change due to a treatment. The following terms are defined to help clarify the proposed procedure for the expression of these changes in a quantitative manner:

C_1 = Value of a parameter (frequency, biomass, etc.) of a species on a control stand at Time-1.

C_2 = Value of the same parameter of the species on a control stand at Time-2.

T_1 = Value of the parameter of the species on a treated stand before treatment but measured at the same time as C_1 .

T_2 = Value of the parameter of the species on the treated stand following treatment but measured at the same time as C_2 .

Starting with the basic premise that $C_1 = T_1$, i.e. when the treated and untreated stands are exact replicas of each other, then the change due to time or season (from Time-1 to Time-2) equals $C_2 - C_1$, and change due to the treatment equals $T_2 - C_2$. However, the difficulty of finding exact replicates of sites is a characteristic of this kind of investigation in most forest communities and the problem needs resolving for most of the forest situations. Due to the natural heterogeneity among different parts of the same stand C_1 did not exactly equal T_1 in the present situation. In cases where $T_1 \neq C_1$, an expected value of a parameter for treated stands ($\hat{T}_2$) analogous to C_2 must be estimated. The simplest assumption, in the absence of any alternative information, is that T_1 would change to $\hat{T}_2$ in the same proportion as C_1 to C_2 (during the same time period, Time-1 to Time-2) if there were no effects of a treatment. The change due to a treatment can algebraically be expressed as:

$$\begin{aligned} \text{Change due to treatment} &= T_2 - \hat{T}_2 \\ &= T_2 - (T_1 \cdot C_2 / C_1) \dots\dots\dots(i) \end{aligned}$$

$$\begin{aligned} \% \text{ Change due to treatment} &= (T_2 - \hat{T}_2) \cdot 100 / \hat{T}_2 \dots\dots\dots(ii) \\ (\text{as \% of } \hat{T}_2) & \end{aligned}$$

By substituting the value of $\hat{T}_2$ in (ii) we get:

$$\% \text{ Change due to Treatment} = ((T_2 C_1 / T_1 C_2) - 1) \cdot 100 \dots\dots(iii)$$

The change is expressed as units of change from $\hat{T}_2$ in equation (i) and as % of $\hat{T}_2$ in equation (iii). The calculated value of % change is minus 100% in cases where the species disappears following a treatment, and the upper limit of the scale of percent change is open-ended. In case of no change the calculated value will be zero.

The procedure is ideally suited to situations where the species are present both on control and treated stands and the two stands are sampled at least once before the application of treatment and once after the treatment. In the present study the data for estimating the effect of fire (comparing logged with logged-burned stands) complied with the above conditions. However, the data for estimating effects of logging (comparing logged-unburned stands with unlogged-unburned stands) were deficient in prelogging measurements in these stands. The use of the present procedure on a sample data to estimate effects of logging and fire (in the logged stands) is illustrated below:

Sample Data				
Species	Time of sampling	% Frequency		
		Unlogged -Unburned	Logged- Unburned	Logged- Burned
X	Time-1	32(C ₁)	60(L ₁)	30(B ₁)
	Time-2	40(C ₂)	90(L ₂)	40(B ₂)

I. Estimating Change Due to Logging

As pointed out earlier the proposed procedure will work better if the first sampling is done on the control as well as the treated stands before the application of a treatment. The problem of lack of total similarity between control and treated stands was compounded by the lack of pre-logging data for comparison between logged and unlogged stands. In this situation and in the absence of any alternative information, the effect of logging calculated on the assumption that the change in a species due to time (from Time-1 to Time-2) on a logged stand would be proportional to its change on an unlogged stand, if there were no effects of logging. The % change due to logging was calculated by the following equation:

$$\% \text{ change logging} = ((L_2 C_1 / L_1 C_2) - 1) \cdot 100 \dots\dots\dots (iv)$$

where, C₁ = Value of a parameter (frequency, biomass etc.)
on Unburned-Unlogged stand at Time-1.

C₂ = Value of the same parameter of the species
on an Unlogged-Unburned stand at Time-2.

L₁ = Value of the parameter of the species on
Logged-Unburned stand at the same time as C₁.

L₂ = Value of the parameter of the species on
the Logged-Unburned stand at the same time
as C₂.

The use of the equation (iv) on sample data is illustrated below:

$$\% \text{ change logging} = ((90 \times 32/60 \times 40) - 1) \cdot 100 = +20\%$$

II. Estimating Change Due To Burning:

The change in species due to fire was simply calculated using the following formula:

$$\% \text{ change fire} = ((B_2 L_1 / B_1 L_2) - 1) \cdot 100 \dots \dots \dots (v)$$

where, L_1 = Value of the parameter of a species on
Logged-Unburned stand before burning
at Time-1.

L_2 = Value of the parameter of the species
on Logged-Unburned stand at Time-2.

B_1 = Value of the parameter of the species on
Logged-Burned stand before burning but measured
at the same time as L_1 .

B_2 = Value of the parameter of the species on Logged-
Burned stand after burning but measured at same
time as L_2 .

For example the % change due to burning for the sample data is calculated as follows:

$$\% \text{ change fire} = ((40 \times 60/30 \times 90) - 1) \cdot 100 = -11.1\%$$

All the changes due to fire presented in this report are fire-changes under logged-burned conditions. Hereafter these will be referred to as changes due to fire or effects of fire.

III. Limitations

- a) We assume that all species change from Time-1 to Time-2 in the ratio of C_2/C_1 . All species may not conform to this assumption.
- b) Where C_1 and T_1 are equal to zero or markedly different from each other, an unreliable estimate of $\hat{T}_2$ ($\hat{L}_2$, $\hat{B}_2$) is expected.

RESULTS AND DISCUSSION

The changes in forest communities due to the impact of forest practices such as logging and light prescribed burning are usually more pronounced in the strata of minor vegetation and shrub undergrowth than the tree stratum in the early stages of succession following logging and especially light fires. This is because these species have shorter life cycles and faster turnover than trees. The results of changes in the herbaceous and shrub strata are presented in this section.

It should be pointed out in the beginning that some of the shrub and tree species occur as components of more than one stratum of the forest community. For example, small seedlings of pines, balsam fir, red maple and regrowth of Populus and Corylus etc. are important components of the herbaceous stratum. As they grow taller these species become important in the shrub and tree strata. As a result we have the same species represented in more than one stratum of vegetation and it may not respond in the same way to logging or fire treatments in all the strata. In this report response of such species is described for each stratum separately.

SHRUB UNDERGROWTH

The number of living stems and the biomass per acre of species occurring in samples are presented in Table 4. Biomass was only measured for hazel (Corylus cornuta), which contributed more than 50% of the total number of stems and the total biomass. The true changes due to fire and logging are hard to derive from these data because the samples following different stand-treatments were collected at different time-of-year. The measured effects are the combined effects of fire intensity, time of the year, reproductive biology, physiological state of the species at the time of burning, etc. The post-burn shrub composition also depends on the available seed source and dispersal of seeds to the burned sites. In spite of these limitations, some tentative conclusions can be drawn.

In the shrub-stratum Abies balsamea, Acer rubrum, Kalmia, Vaccinium sp. and seedlings of Picea and Pinus were temporarily eliminated by light burning. Hazel (Corylus cornuta) and Amelanchier sp. were partially controlled by one light fire. The response of Betula papyrifera and Populus tremuloides to logging and burning cannot be evaluated because of their absence in preburn samples. It appears, however, that these species are favoured by fire.

Table 4. ^{a/} Shrub* Composition Before And After Stand Treatments In Stand 102

Species	Before Logging ^{1/}			After Logging ^{2/}			After Burn ^{3/}		
	Stems/ ha	Height (m) Min. Max.	Biomass (kg/ha.)	Stems/ ha	Height (m) Min. Max.	Biomass (kg/ha.)	Stems/ ha	Height (m) Min. Max.	Biomass (kg/ha.)
<u>Abies balsamea</u>	1,331	0.30 0.37	-	532	0.40 0.40	-	-	- -	-
<u>Acer rubrum</u>	798	0.91 1.52	-	1,331	0.37 0.67	-	-	- -	-
<u>Amelanchier</u> sp.	932	1.22 2.44	-	-	- -	-	88	0.30 0.30	-
<u>Betula papyrifera</u>	-	- -	-	-	- -	-	1,774	0.30 0.30	-
<u>Corylus cornuta</u>	45,515	0.55 1.65	1,604	16,236	0.58 1.74	716	6,563	0.30 0.91	443
<u>Kalmia angustifolia</u>	532	0.30 0.30	-	-	- -	-	-	- -	-
<u>Picea glauca</u>	-	- -	-	133	0.30 0.30	-	-	- -	-
<u>Pinus strobus</u>	2,129	0.37 0.52	-	1,996	0.30 0.34	-	-	- -	-
<u>Populus tremuloides</u>	-	- -	-	-	- -	-	4,789	0.30 0.52	-
<u>Vaccinium</u> sp.	532	0.30 0.61	-	-	- -	-	-	- -	-
All species	51,770	- -	-	20,229	- -	-	13,212	- -	-

^{a/} Table compiled from unpublished data (C.E. Van Wagner)

* Shrubs included all semi-shrubs, shrubs and tree seedlings of 30 cm to 270 cm height

^{1/} Sampled Oct. 8/71

^{2/} Sampled May 23/72

^{3/} Sampled Aug. 15/72

HERBACEOUS VEGETATION

The changes due to fire and logging could result in the introduction of new or exclusion of some of the existing species. Other species may be intermediate in their response to burning and logging. The absence of a species in samples does not mean that it was non-existent in stands from which the samples were taken. It is possible that species not recorded in samples were either completely absent in stands or were present in such a low abundance that the sample-size was inadequate to detect their presence.

Quantitative Changes In Frequency And Biomass

The response of individual species to logging and burning is difficult to assess because of the following:

- i) control stands are not totally similar to the treated stands before treatments,
- ii) seasonal changes in species are of different magnitudes before and after stand treatments,
- iii) changes following fire and/or logging depend on 1) site, 2) stand composition, 3) time of sampling, 4) abundance of a species present before treatment, 5) intensity of treatment, 6) post-treatment dispersal of seeds to the site, etc.

Percent frequency and biomass of all species occurring in stands 102A, 102B, 102C and 102E are given in Appendices I and II. In this section, only the important species will be considered in detail. The data for these species on undisturbed, logged and logged-burned stands are presented in Table 5. The values for logged-burned conditions are the average of values for stands 102A, 102B-hf and 102B-bf.

Quantitative changes in individual species following logging and burning were calculated for important species by the method described on pages 9 to 12. The unlogged-unburned stand was considered as a control for estimating the effects due to logging in logged-unburned stands, and the logged-unburned stand was used as a control for calculating the change due to fire in logged-burned stands. There were no unlogged-burned stands available for sampling. Calculated changes in frequency and biomass of important species are presented in Appendices III and IV.

A study of Appendices III and IV show that the changes in frequency and biomass of a species may not be of the same kind following a logging or a burning treatment. The species can be classified into 5 categories depending on their response in frequency and biomass to logging and fire treatments.

Table 5. Average Percent Frequency and Average Biomass of Important Species of Minor-Vegetation in Control, Logged and Logged-Burned Stands.

Species	Month	Frequency ^{1/}			Biomass ^{2/}		
		UL-UB ^{4/}	L-UB ^{5/}	L-B ^{6/}	UL-UB	L-UB	L-B
<u>Acer rubrum</u>	June ^{3/}	5	5	3	0.88	0.01	0.04
	Aug.	0	10	10	0.00	0.78	0.28
<u>Aralia nudicaulis</u>	June	60	65	28	13.09	37.19	17.18
	Aug	60	95	37	22.57	46.87	1.49
<u>Aralia racemosa</u>	June	0	0	0	0.00	0.00	0.00
	Aug.	0	0	13	0.00	0.00	0.78
<u>Aster macrophyllus</u>	June	65	55	55	11.50	5.90	9.20
	Aug.	65	75	37	18.09	31.47	6.92
<u>Betula papyrifera</u>	June	0	5	8	0.00	0.29	0.10
	Aug.	0	30	18	0.00	0.09	0.02
<u>Carex sp.</u>	June	20	20	32	0.69	0.40	2.46
	Aug.	15	30	62	1.41	2.32	2.00
<u>Convolvulus spithameus</u>	June	0	0	0	0.00	0.00	0.00
	Aug.	0	0	18	0.00	0.00	1.01
<u>Cornus canadensis</u>	June	35	10	5	3.68	0.23	2.20
	Aug.	25	30	7	3.13	1.45	0.30
<u>Corylus cornuta</u>	June	30	10	38	6.31	0.53	7.68
	Aug.	20	45	48	2.41	5.65	5.60
<u>Gaultheria procumbens</u>	June	45	20	45	1.81	0.41	3.23
	Aug.	5	85	17	0.36	1.12	0.10
<u>Geranium bicknellii</u>	June	0	0	0	0.00	0.00	0.00
	Aug.	0	5	23	0.00	0.01	4.11
<u>Hepatica americana</u>	June	0	10	0	0.00	5.68	0.00
	Aug.	0	35	0	0.00	4.34	0.00
<u>Linnaea borealis</u>	June	20	30	10	2.16	0.42	0.15
	Aug.	15	15	0	0.37	0.22	0.00
<u>Lycopodium lucidulum</u>	June	0	0	3	0.00	0.00	3.54
	Aug.	0	0	0	0.00	0.00	0.00

Table 5. Average Percent Frequency and Average Biomass of Important Species of Minor-Vegetation in Control, Logged and Logged-Burned Stands.
(Cont'd.)

Species	Month	Frequency ^{1/}			Biomass ^{2/}		
		UL-UB ^{4/}	L-UB ^{5/}	L-B ^{6/}	UL-UB	L-UB	L-B
<u>Lycopodium obscurum</u>	June ^{3/}	15	0	10	8.12	0.00	0.57
	Aug.	5	20	0	4.81	4.50	0.00
<u>Maianthemum canadense</u>	June	80	90	63	17.32	31.29	24.66
	Aug.	95	100	85	15.28	15.46	0.49
<u>Mitchella repens</u>	June	0	0	3	0.00	0.00	16.40
	Aug.	5	10	0	0.11	10.95	0.00
<u>Oryzopsis asperifolia</u>	June	10	80	30	1.96	24.12	9.74
	Aug.	30	70	22	1.83	11.16	0.64
<u>Pinus resinosa</u>	June	0	0	3	0.00	0.00	4.10
	Aug.	0	0	0	0.00	0.00	0.00
<u>Pinus strobus</u>	June	10	15	18	0.14	2.44	2.62
	Aug.	15	15	0	0.31	0.45	0.00
<u>Populus tremuloides</u>	June	10	10	12	0.16	0.12	0.04
	Aug.	0	45	8	0.00	44.77	15.78
<u>Pteridium aquilinum</u>	June	5	15	10	5.78	8.12	9.11
	Aug.	35	25	48	15.93	17.20	53.48
<u>Rhus radicans</u>	June	0	0	10	0.00	0.00	0.64
	Aug.	5	0	0	0.52	0.00	0.00
<u>Trientalis borealis</u>	June	45	45	13	0.54	0.42	0.19
	Aug.	40	25	0	0.60	0.27	0.00
<u>Vaccinium angustifolium</u>	June	0	20	22	8.91	4.21	1.63
	Aug.	10	30	5	3.28	4.51	0.15
<u>Vaccinium myrtilloides</u>	June	0	10	0	0.00	8.70	5.25
	Aug.	5	25	2	0.60	7.60	0.15
<u>Viburnum acerifolium</u>	June	0	5	12	0	0.30	1.84
	Aug.	0	10	5	0	2.70	0.03

Table 5. Average Percent Frequency and Average Biomass of Important Species of Minor-Vegetation in Control, Logged and Logged-Burned Stands. (Concl'd.)

Species	Month	Frequency ^{1/}			Biomass ^{2/}		
		UL-UB ^{4/}	L-UB ^{5/}	L-B ^{6/}	UL-UB	L-UB	L-B
<u>Viola</u> sp.	June ^{3/}	15	5	0	<0.00	0.20	0.00
	Aug.	15	10	10	0.20	0.10	0.00
<u>Waldsteinia fragarioides</u>	June	45	5	7	2.8	0.1	0.29
	Aug.	60	0	3	3.9	0.0	0.14

^{1/} Frequency = % occurrence

^{2/} Biomass = gm/5m²

^{3/} All June samples are pre-burn

^{4/} UL-UB = unlogged-unburned

^{5/} L-UB = logged-unburned

^{6/} L-B = logged-burned

NOTE: Data for logged-burned is an average of values of 3 stands:

102A, 102B-bf, 102B-hf. See Appendices I and II.

- i) Species which show an increase in frequency as well as biomass. This kind of change means an increase in the number of stems and possibly larger plants.
- ii) Species which show an increase in frequency and decrease in biomass (larger number of smaller individuals).
- iii) Species which show a decrease in frequency and increase in biomass (smaller number of larger individuals).
- iv) Species which show a decrease in frequency as well as a decrease in biomass (smaller number of individuals and possibly smaller individuals).
- v) Species which show no change ($\pm$ 5% change).

Response-category as well as abundance classes are listed in Table 6. The following general comments can be made on the effects of logging and burning on the species occurring in the herbaceous layer of the pine-mixedwoods:

- i) Only 6 of the 29 species showed a similar response to both logging and burning. These are Acer rubrum, Geranium bicknellii, Pinus strobus, Trientalis borealis, Vaccinium myrtilloides, and Waldsteinia fragarioides. Most of these species are of low abundance.
- ii) Logging promotes an increase in frequency as well as biomass of 40% of the species, whereas burning on logged stands has a similar effect only on 17% of the important species.
- iii) Majority of the species in category-1 under logging shift to category-4 and category-5 after burning.
- iv) Under logging species of all abundance classes are included in response-category-1 whereas after-burning species in this category are predominantly of low abundance.
- v) Category-3 is least represented both under logging and burning.
- vi) Most species after burning show an overall decrease in frequency and biomass in the early stages following burning and logging as shown below:

Table 6. Response of Minor Vegetation in Pine-Mixedwoods to Logging and Burning

Response Category	Stand Treatment	
	Logging	Burning
1. Increase in frequency and increase in biomass	Gaultheria procumbens	Pteridium aquilinum (7)
	Aster macrophyllus	Geranium bicknellii (8)
	Corylus cornuta	Aralia racemosa (9)
	Populus tremuloides	Convolvulus spithameus (9)
	Carex sp.	Acer rubrum (10)
	Cornus canadensis	
	Vaccinium angustifolium	
	Lycopodium obscurum	
	Acer rubrum	
	Geranium bicknellii	
	Mitchella repens	
	Viburnum acerifolium	
2. Increase in frequency and decrease in biomass	Aralia nudicaulis	Maianthemum canadense (2)
	Hepatica americana	Carex sp. (4)
	Betula papyrifera	Oryzopsis asperifolia (8)
	Vaccinium myrtilloides	Vaccinium myrtilloides (10)
	Viola sp.	Viola sp. (10)
3. Decrease in frequency and increase in biomass	Linnaea borealis	Populus tremuloides (10)

Table 6. Response of Minor Vegetation in Pine Mixedwoods to Logging and Burning (Concl'd.)

Response Category	Stand Treatment	
	Logging	Burning
4. Decrease in frequency and decrease in biomass	Maianthemum canadense	Aralia nudicaulis (1)
	Oryzopsis asperifolia	Aster macrophyllus (5)
	Trientalis borealis	Gaultheria procumbens (6)
	Pteridium aquilinum	Corylus cornuta (7)
	Pinus strobus	Vaccinium angustifolium (8)
	Waldsteinia fragarioides	Betula papyrifera (9)
		Pinus strobus (9)
		Trientalis borealis (9)
		Viburnum acerifolium (9)
		Cornus canadensis (10)
5. No effect		Linnaea borealis (10)
		Lycopodium lucidulum (10)
		L. obscurum (10)
		Mitchella repens (10)
		Pinus resinosa (10)
		Rhus radicans (10)
		Waldsteinia fragarioides (10)
	Aralis racemosa	
	Convulus spithameus	Hepatica americana (10)
	Lycopodium lucidulum	
5. No effect	Pinus resinosa	
	Rhus radicans	

*Number in parenthesis is the abundance class for species depending on its maximum frequency in a sample from logged or burned stands.

<u>Response-Category</u>	<u>% of Important Species</u>	
	<u>Logging</u>	<u>Burning</u>
1	41	17
2	17	17
3	4	4
4	21	57
5	17	4

- vii) Most of species can reproduce both vegetatively, and by seeds but majority were observed to regenerate from underground roots and stems. A detailed study of the reproduction biology of these species is needed to evaluate their vegetative-regenerative capacity in relation to logging and fire. There are reports in literature that the species of minor vegetation inhibit or promote regeneration of trees, shrubs and herbs (Brown 1967). Such information is lacking for pine-mixedwoods. The only species, observed to reproduce by seeds were Geranium, Convolvulus, and Acer rubrum. These species were predominant after fire only.
- viii) Under logging, category-1 contains about equal percentages of spring and summer flowering species whereas in burned stands they occur in 1:2 ratio. This may simply be due to the fact that stands were burnt in July and spring species did not find it suitable to grow to their full potential at the time of sampling.
- ix) Categories 4 and 5 in both logged and burned stands are dominated by species which flower during spring.

There is some evidence from the presently available information (Appendices I and II) that the kind of responses of individual species to fire are related to the kind of fire (headfire or backfire), fire intensity and the time (of the year) of burning. Species fall under three groups according to their response to kind and intensity of fire:

- i) Species in which change due to fire is of the same kind and does not depend on fire intensity or time of burning, e.g. Maianthemum, Aralia nudicaulis.
- ii) Species in which change is directly proportional to fire intensity and is probably independent of time of burning, e.g. Aster macrophyllus.
- iii) Species in which change is dependent both on fire intensity as well as time of burning, e.g. Carex, Pteridium.

This aspect of species changes in relation to fire intensity and time of burning warrants further study to evaluate the role of fire intensity and time of burning for controlling the undesirable or promoting the desirable species temporarily.

An increase or decrease in one species imposes a change in the relative importance of every other species in the forest community. Simply, the relative importance of a species can be expressed as its relation to others in a community, either by its relative frequency or its relative biomass. These parameters for important species are given in Appendix V. The rank of more important species (which contributed to 80% of the total biomass or 80% of the sum of percent frequencies of all species) in unlogged-unburned, logged-unburned and logged-burned stands are listed in Table 7.

It is interesting to note that the three most important species; Maianthemum, Aster and Aralia are the same in unlogged-unburned and logged-unburned stands both on the basis of % relative frequency and % relative biomass. However, Aster becomes less important and Carex, Corylus and Pteridium improve in their order of the relative frequencies after burning. Pteridium and Populus, contributing small percentages to the total biomass in unburned stands, account for over 60% of the total biomass after burning on logged stands. These drastic changes in biomass indicate different pressures on the available physical resources in the forest community, i.e. nutrient budget, water budget, etc., and changes in the input to the community viz. light, rain interception, nutrient quantity and quality, utilization of minerals released immediately following burning, etc.

Change In Number Of Species, Abundance-class Frequency And Total Biomass:

In the early stages of succession following logging and burning, there is little or no change in total number of important species. In Fig. 2, the number of species belonging to each abundance class are plotted for unlogged-unburned, logged-unburned and logged-burned stands. In the three cases about 50% of the 29 species belong to the classes of least abundances (0 - 10). Logging seems to favour some species of the higher abundance classes. Although the frequency distribution of species practically stays unchanged, it is the individual species that perform differently in three stand treatments (Appendices III and IV).

Following logging the biomass of minor vegetation increased by 80% and after burning there was an immediate decrease of 23 to 86% in biomass. The magnitude of the decrease varied with intensity of fire as well as the time of burning (Table 8).

Table 7. Descending Order^{1/} of Species^{2/} of Minor-Vegetation in Undisturbed, Logged and Logged-Burned Stands of Pine-Mixedwoods Based on their Relative Frequency and Relative Biomass

Relative Frequency	Relative Biomass
1. <u>Unlogged-Unburned:</u>	
Maianthemum canadense	Aralia nudicaulis
Aster macrophyllus	Maianthemum canadense
Aralia nudicaulis	Aster macrophyllus
Waldsteinia fragarioides	Pteridium aquilinum
Trientalis borealis	Lycopodium obscurum
Gaultheria procumbens	Vaccinium angustifolium
Cornus canadensis	Corylus cornuta
Corylus cornuta	Cornus canadensis
Carex sp.	Waldsteinia fragarioides
Pteridium aquilinum	Oryzopsis asperifolia
Linnaea borealis	
Oryzopsis asperifolia	
Viola sp.	
2. <u>Logged-Unburned:</u>	
Maianthemum canadense	Aralia nudicaulis
Aralia nudicaulis	Maianthemum canadense
Oryzopsis asperifolia	Oryzopsis asperifolia
Aster macrophyllus	Aster macrophyllus
Gaultheria procumbens	Populus tremuloides
Trientalis borealis	Pteridium aquilinum
Populus tremuloides	Vaccinium myrtilloides
Carex sp.	Hepatica americana
Vaccinium angustifolium	Vaccinium angustifolium
Corylus cornuta	
Linnaea borealis	
Pteridium aquilinum	
Cornus canadensis	
Vaccinium myrtilloides	
Pinus strobus	
Viburnum acerifolium	
Viola sp.	

Table 7. Descending Order^{1/} of Species^{2/} of Minor-Vegetation in Undisturbed, Logged and Logged-Burned Stands of Pine-Mixedwoods Based on their Relative Frequency and Relative Biomass (Concl'd.)

Relative Frequency	Relative Biomass
3. <u>Logged-Burned:</u>	
<i>Maianthemum canadense</i>	<i>Pteridium aquilinum</i>
<i>Carex</i> sp.	<i>Populus tremuloides</i>
<i>Corylus cornuta</i>	<i>Aster macrophyllus</i>
<i>Pteridium squilinum</i>	<i>Corylus cornuta</i>
<i>Aralia nudicaulis</i>	<i>Geranium bicknellii</i>
<i>Aster macrophyllus</i>	<i>Aralia nudicaulis</i>
<i>Oryzopsis asperifolia</i>	
<i>Geranium bicknellii</i>	

^{1/}Ordering is based on the average of June and August frequency and biomass values of a species in unburned stands. In burned stands, ranking is based on the average of post-burn values for 3 stands. For actual % relative frequency and % relative biomass values, see Appendix V.

^{2/}Only those species which contribute 80% of the biomass or 80% of the sum of frequencies of all species, are included in this Table.

Fig. 2. Frequency distribution of species among abundance classes in Unlogged-Unburned, Logged-Unburned and Logged-Burned Stands 51 days after burning.

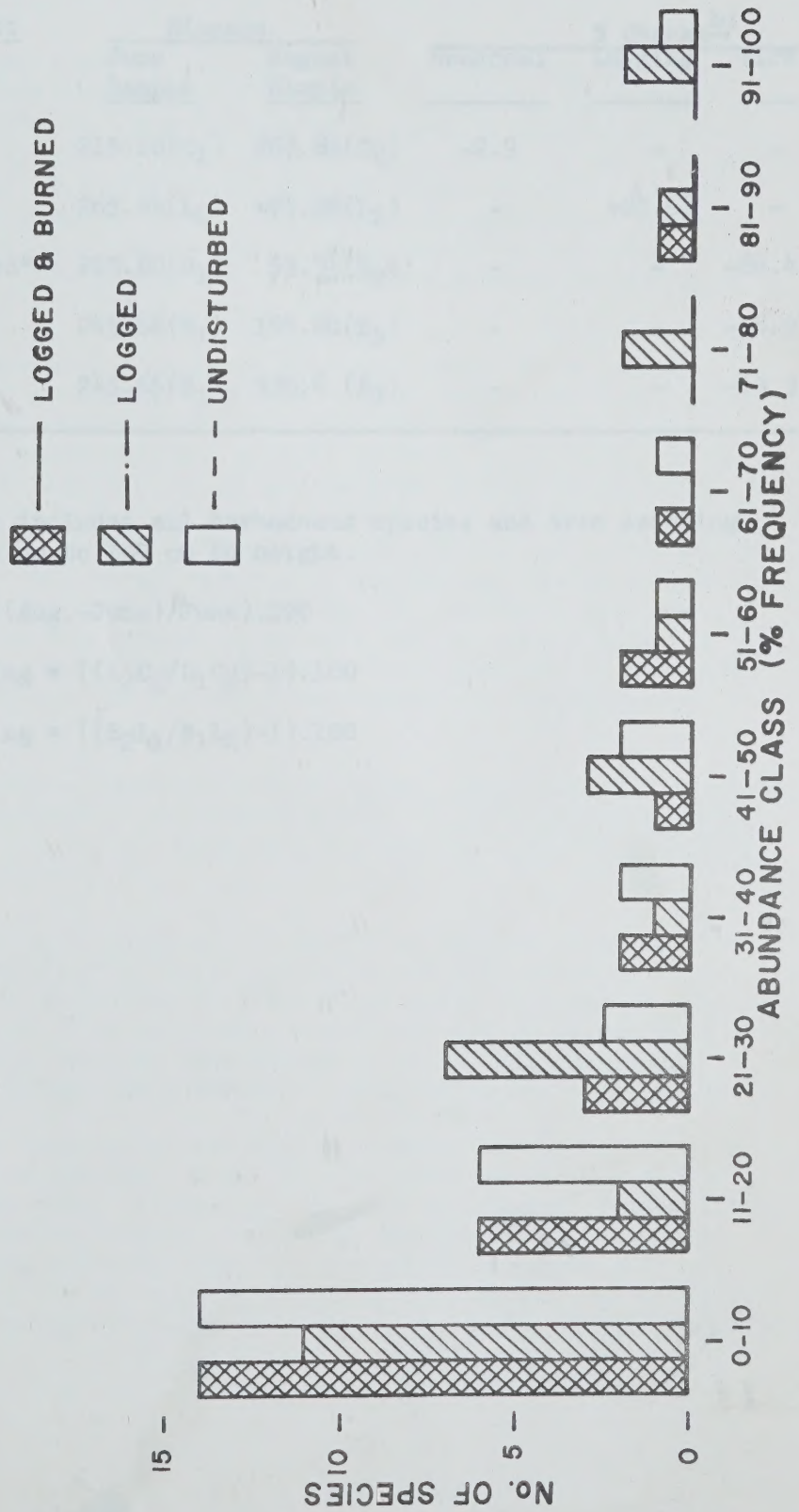


Table 8. Biomass (kg/ha) Of Herbaceous^{a/} Vegetation In Pine-Mixedwoods

Stand	Stand Treatment	Biomass		Seasonal	% Change ^{b/}	
		June Sample	August Sample		Logging	Fire
102E	Natural	215.10(C ₁)	208.84(C ₂)	-2.9	-	-
102C	Logged	265.44(L ₁)	465.56(L ₂)	-	+80.68	-
102A-hf	Logged & Burned*	223.80(B ₁)	53.34(B ₂)	-	-	-86.4
102B-hf	-do-**	245.66(B ₁)	185.80(B ₂)	-	-	-56.9
-bf	-do-**	245.66(B ₁)	330.6 (B ₂)	-	-	-23.3

^{a/} Herbaceous vegetation includes all herbaceous species and tree seedlings, shrubs and semi-shrubs up to 100 cm in height.

^{b/} % Seasonal change = ((Aug.-June)/June).100

% Change due to logging = ((L₂C₁/L₁C₂)-1).100

% Change due to burning = ((B₂L₁/B₁L₂)-1).100

* Burned July 17/72

** Burned July 6/72

CONCLUSIONS

The conclusions drawn in this report have limited application and are only valid for the stands included in this sample or other very similar pine-mixedwood stands. The calculated changes in individual species are applicable to that specific period from the application of the treatments to the time of sampling. The effects of fire are only applicable to the partially logged pine-mixedwood stands. No burned-unlogged stands were available during the course of this study. It is suspected that the same species would show a different response to prescribed burning in unlogged natural stands.

Significant variations occur in the composition (tree, shrubs and minor-vegetation) in experimental stands. These variations occurred in the number of species, their abundance and relative importance. For a meaningful analysis and interpretation of data in these situations, it is necessary to collect the data for shrubs and herbaceous vegetation twice during one year, before and after a logging or burning treatment. This procedure would help sort out the similarities and differences among control and treated stands prior to the application of treatments, estimate seasonal changes in species and partition the changes due to treatments and time. The procedure proposed in this report works well for species of moderate to high abundance. The procedure will give unreliable estimates of change for less common species. This is due to their inadequate representation in samples.

In the shrub layer, several species (Abies, Acer, Kalmia, Vaccinium) can be temporarily eliminated by prescribed fires. Hazel (Corylus cornuta) can be partially controlled by one light burning whereas Betula and Populus are favoured by one light fire.

There is probably an increase in number of species of minor vegetation following logging. It could not be tested with confidence in the absence of comparable data from the same stand prior to logging. The change in the total number of species as a result of burning is not significant, however transient species reproducing by seeds, viz. Geranium, Convolvulus, Polygonum, Prunus appeared three weeks following the burning.

Following both logging and burning treatments and irrespective of the change in number of species, there is a definite change in species and their abundance. The total changes are the sum of seasonal changes plus changes due to logging and/or burning. Seasonal changes in logged stands are of a smaller magnitude compared with the changes in unlogged-unburned stands. This is probably due to wide fluctuations in temperature, moisture and light regimes in undisturbed stands from spring to fall. Biomass increased

after logging and decreased after a burning treatment (at least in early stage). Seasonally, there was little change in biomass in undisturbed stands, but biomass increased substantially from spring to summer in logged-unburned stands.

The species that are common to undisturbed, logged and logged-burned stands show distinct changes in their seasonal growth patterns after logging and/or burning. The important species fall under 5 response-categories depending on the change in their frequency and biomass following logging and burning: i) Increasing in both frequency and biomass, ii) Increasing in frequency and decreasing in biomass, iii) Decreasing in frequency and increasing in biomass, iv) Decreasing in frequency and decreasing in biomass, v) No effect. Forty percent of the important species after logging and 14 percent after burning belonged to category 1. There was a general decrease in the biomass of species after burning. This could partially be due to the sub-normal growth of the vegetation during the remainder of the growing season (1972) after burning.

There was no apparent relationship between the reproductive biology of the species and their response category. Some of the species like Geranium and Convolvulus which were common after fire were of seed origin. Category I is dominated by summer-species while category 4 and 5 were represented more by spring-species in burned stands.

The relative importance of species is least affected by logging and the three most important species in logged and unlogged stands were Aster, Aralia and Maianthemum based on biomass as well as frequency. However, Pteridium and Populus contributed more than 50% of biomass in the early stages of succession following fire. The successional changes in these species, in particular, in relation to pine regeneration should be emphasized in future.

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Appendix I. Percent Frequencies^{1/} Of Plant Species In Pine-Mixedwoods During June And August.

SPECIES	STANDS									
	102E		102C		102A		102B-hf		102B-bf	
	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.
<i>Abies balsamea</i>	15.0									
<i>Ambrosia artemisiifolia</i>				5.0						
<i>Acer rubrum</i>	5.0		5.0	10.0			5.0		5.0	30.0
<i>Amelanchier</i> sp.	5.0				5.0					
<i>Apocynum androsaemifolium</i>										5.0
<i>Aralia nudicaulis</i>	60.0	60.0	65.0	95.0	45.0	25.0	20.0	35.0	20.0	50.0
<i>Aralia racemosa</i>								20.0		20.0
<i>Aster ciliolatus</i>		5.0		5.0						
<i>Aster macrophyllus</i>	65.0	65.0	55.0	75.0	35.0	25.0	65.0	35.0	65.0	50.0
<i>Betula papyrifera</i>			5.0	30.0	5.0		10.0	35.0	10.0	20.0
<i>Carex</i> sp.	20.0	15.0	20.0	30.0	25.0	30.0	35.0	80.0	35.0	75.0
<i>Chimaphila umbellata</i>			5.0							
<i>Clintonia borealis</i>	10.0	20.0	15.0	5.0			5.0		5.0	
<i>Convolvulus spithameus</i>								50.0		5.0
<i>Cornus canadensis</i>	35.0	25.0	10.0	30.0	5.0		5.0	15.0	5.0	5.0
<i>Corydalis sempervirens</i>										5.0
<i>Corylus cornuta</i>	30.0	20.0	10.0	45.0	35.0	35.0	40.0	50.0	40.0	60.0
<i>Diervilla lonicera</i>		5.0	5.0	5.0				5.0		
<i>Fragaria virginiana</i>			5.0	5.0			5.0		5.0	
<i>Gaultheria procumbens</i>	45.0	5.0	20.0	85.0	35.0	15.0	50.0	5.0	50.0	30.0

[illegible]

Appendix I. Percent Frequencies^{1/} Of Plant Species In Pine-Mixedwoods During June And August (Concl'd.)

SPECIES	STANDS									
	102E		102C		102A		102B-hf		102B-bf	
	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.
<i>Populus tremuloides</i>	5.0		10.0	45.0				15.0		10.0
<i>Prenanthes altissima</i>								10.0		
<i>Prunus pensylvanica</i>								5.0		
<i>Pteridium aquilinum</i>	5.0	35.0	15.0	25.0	10.0	35.0	10.0	45.0	10.0	65.0
<i>Pyrola rotundifolia</i>				15.0						
<i>Pyrola secunda</i>	5.0		5.0	5.0						
<i>Quercus rubra</i>				5.0						
<i>Rhus radicans</i>		5.0					15.0		15.0	
<i>Rubus pubescens</i>	5.0	5.0		10.0		5.0				10.0
<i>Rubus allegheniensis</i>										5.0
<i>Streptopus roseus</i>	5.0			5.0						
<i>Trientalis borealis</i>	45.0	40.0	45.0	25.0	10.0		15.0		15.0	
<i>Vaccinium angustifolium</i>	15.0	10.0	20.0	30.0	35.0		15.0		15.0	15.0
<i>Vaccinium myrtilloides</i>		5.0	10.0	25.0						5.0
<i>Viburnum acerifolium</i>			5.0	10.0	5.0		15.0		15.0	15.0
<i>Viola</i> sp.	15.0	15.0	5.0	10.0		5.0		20.0		5.0
<i>Waldsteinia fragarioides</i>	45.0	60.0	5.0				10.0	10.0	10.0	
Mushroom		15.0		20.0						10.0

^{1/}% Frequency = Percentage of twenty 1/2 m x 1/2 m quadrats in which a species was present.

Appendix II. Biomass ($g/5m^2$) of Different Species In Five Pine-Mixedwood Stands

SPECIES	STANDS														
	102E			102C			102A			102B-hf			102B-bf		
	June	Aug.	June	June	Aug.	Aug.	June	Aug.	June	June	Aug.	June	June	Aug.	
Abies balsamea	12.59														
Ambrosia artemisiifolia				1.26											
Acer rubrum (Red maple)	0.88		0.01	0.68					0.06			0.06		0.85	
Amelanchier sp.	0.63					0.21									
Apocynum androsaemifolium														0.40	
Aralia nudicaulis (Wild sarsaparilla)	13.09	22.57	37.19	46.87		16.21		2.27	17.67	0.88		17.67	17.67	1.33	
Aralia racemosa										1.43				0.92	
Aster ciliolatus		0.42		0.93											
A. macrophyllus	11.50	18.09	5.90	31.47		4.64		3.76	11.48	6.44		11.48	11.48	10.56	
Betula papyrifera (White birch)			0.29	0.09		0.09			0.10	0.04		0.10	0.10	0.02	
Carex sp.	0.69	1.41	0.40	2.32		2.94		0.32	2.23	3.15		2.23	2.23	2.52	
Chimaphila umbellata (Prince's-pine)			0.39												
Clintonia borealis (Yellow clintonia)	1.62	4.18	0.72	1.33					0.51				0.51		

Appendix II. Biomass ($\text{g}/5\text{m}^2$) of Different Species In Five Pine-Mixedwood Stands (Cont'd.)

SPECIES	STANDS											
	102E			102C			102A			102B-hf		
	June	Aug.	June	June	Aug.	Aug.	June	June	Aug.	June	June	102B-bf Aug.
<i>Convolvulus spithameus</i>										2.96		0.07
<i>Cornus canadensis</i> (Bunchberry)	3.68	3.13	0.23	1.45	0.14		2.23		0.06	2.23		0.02
<i>Corydalis sempervirens</i>												0.07
<i>Corylus cornuta</i> (Hazel)	6.31	2.41	0.53	5.65	14.52	1.77	4.26		4.17	4.26		10.87
<i>Diervilla lonicera</i> (Bush-honeysuckle)		0.02	0.29	1.69		0.18			0.17			
<i>Fragaria virginiana</i> (Common strawberry)			0.12	0.61			0.03			0.03		
<i>Gaultheria procumbens</i> (Wintergreen)	1.81	0.36	0.41	1.12	1.79	0.05	3.95		0.01	3.95		0.24
<i>Geranium bicknellii</i>				0.01		1.46			8.89			2.00
<i>Goodyera repens</i> (Rattle snake plantain)				0.03								
<i>Hepatica americana</i>			5.68	4.34								
<i>Linnaea borealis</i> (Twin-flower)	2.16	0.37	0.42	0.22	0.42		0.02			0.02		

Appendix II. Biomass ($g/5m^2$) Of Different Species In Five Pine-Mixedwood Stands (Cont'd.)

SPECIES	STANDS											
	102E			102C			102A			102B-hf		
	June	Aug.	June	June	Aug.	June	June	Aug.	June	Aug.	June	102B-bf Aug.
<i>Lonicera canadensis</i> (Fly honeysuckle)					1.86					0.65		
<i>Lycopodium alpinum</i> (Club moss)									2.07		2.07	
<i>Lycopodium complanatum</i> (Ground cedar)									0.11		0.11	0.01
<i>Lycopodium lucidulum</i> (Club moss)									5.31		5.31	
<i>Lycopodium obscurum</i> (Ground pine)	8.12	4.81			4.54				0.86		0.86	
<i>Maianthemum canadense</i> (Wild Lily of the Valley)	17.32	15.28	31.29	15.46	31.29	0.63	21.35	0.29	21.35	0.29	21.35	0.56
<i>Mitchella repens</i>		0.11		10.95			24.66		24.66		24.66	
<i>Oryzopsis asperifolia</i>	1.96	1.83	24.12	11.16	24.12	0.57	2.56	0.90	2.56		2.56	0.46
<i>Osmunda claytoniana</i>	6.01											
<i>Panicum</i> sp.								0.30				
<i>Picea glauca</i> (White spruce)				5.11								

Appendix II. Biomass ($g/5m^2$) of Different Species In Five Pine-Mixedwood Stands (Cont'd.)

SPECIES	STANDS											
	102E			102C			102A			102B-hf		
	June	Aug.	June	June	Aug.	June	June	Aug.	June	June	Aug.	102B-bf June Aug.
<i>Pinus resinosa</i> (Red pine)									6.19			6.19
<i>Pinus strobus</i> (White pine)	0.14	0.31	2.44	0.45		2.44			2.72			2.72
<i>Polygala paucifolia</i> (Flowering Wintergreen)	0.02			0.22					0.34			0.34
<i>Polygonum cilinode</i> (Fringed bindweed)											3.33	
<i>Populus tremuloides</i> (Trembling aspen)	0.16		0.12	44.77							2.91	44.45
<i>Prenanthes altissima</i> (White lettuce)											0.25	
<i>Prunus pennsylvanica</i>												0.02
<i>Pteridium aquilinum</i> (Bracken fern)	5.78	15.93	8.12	17.20		7.34	15.66		10.00	55.85	10.00	88.93
<i>Pyrola rotundifolia</i>				0.28								
<i>Pyrola secunda</i>	0.36		0.28	0.08								
<i>Quercus rubra</i> (Red oak)				3.97								
<i>Rhus radicans</i> (Poison ivy)		0.52							0.97			
<i>Rubus pubescens</i> (Dwarf blackberry)	0.84	0.66		0.07			<0.00					0.10

Appendix II. Biomass ($g/5m^2$) of Different Species In Five Pine-Mixedwood Stands (Concl'd.)

SPECIES	STANDS											
	102E			102C			102A			102B-hf		
	June	Aug.	June	June	Aug.	June	June	Aug.	June	June	Aug.	102B-bf June Aug.
Rubus allegheniensis (Blackberry)												<0.00
Streptopus roseus (Rose twisted-stalk)	0.47				0.10							
Trientalis borealis	0.54	0.60	0.42	0.27	0.12		0.22		0.22			
Vaccinium angustifolium (low bush blueberry)	8.91	3.28	4.21	4.51	4.13		0.38		0.38		0.45	
Vaccinium myrtilloides (Sour top blueberry)		0.58	8.69	7.65							0.46	
Viburnum acerifolium (Maple leaf viburnum)			0.32	2.68	1.71		1.90		1.90		0.10	
Viola sp.	0.03	0.24	0.16	0.12		<0.00		0.05			0.01	
Waldsteinia fragarioides (Barren-strawberry)	2.77	3.88	0.06				0.44	0.42	0.44			
Mushrooms		3.43		1.26								0.03

Appendix III. Changes In Percent Frequency Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire.
A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An
Unlogged-Unburned Stand.

Abundance ^{a/} Class (% Frequency June)	Species	Control			Logged			Logged-Burned				
		C ₁	C ₂	% seasonal ^{b/} change	L ₁	L ₂	L ₂ ^	% treatment ^{c/} (logging) change	B ₁	B ₂	B ₂ ^	% treatment ^{d/} (burning) change
91-100 -		80	95	+19	90	100	107	-6	63	85	70	+21
81-90 -		60	60	0	65	95	65	+46	28	37	41	-10
71-80 Maianthemum canadense		65	65	0	55	75	55	+36	55	37	75	-50
61-70 Aralia nudicaulis												
Aster macrophyllus												
51-60 -												
41-50 Gaultheria procumbens		45	5	-89	20	85	2	+3725	45	17	191	-91
Trientalis borealis		45	40	-11	45	25	40	-38	13	0	7	-100
Waldsteinia fragarioides		45	60	+33	5	0	7	-100	7	3	0	-ve
Cornus canadensis		35	25	-29	10	30	7	+320	5	7	15	-53
21-30 Corylus cornuta		30	20	-33	10	45	7	+575	38	48	171	-72
11-20 Carex sp.		20	15	-25	20	30	15	+100	32	62	48	+29

Appendix III. Changes In Percent Frequency Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire.
 A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An
 Unlogged-Unburned Stand (Cont'd.)

Abundance ^{a/} Class	Species	Control				Logged				Logged-Burned		
		C ₁	C ₂	% seasonal ^{b/} change	L ₁	L ₂	L ₂	L ₂	% treatment ^{c/} (logging) change	B ₁	B ₂	% treatment ^{d/} (burning) change
11-20	Linnaea borealis	20	15	-25	30	15	22		-33	10	0	5
	Lycopodium obscurum	15	5	-67	0	20	-		+ve	10	0	-
	Viola sp.	15	15	0	5	10	5		+100	0	10	0
0-10	Acer rubrum	5	0	-100	5	10	0		+ve	3	10	6
	Aralia racemosa	0	0	0	0	0	0		-	0	13	0
	Betula papyrifera	0	0	-	5	30	-		+ve	8	18	48
	Convolvulus spithameus	0	0	-	0	0	-		-	0	18	-
	Geranium bicknellii	0	0	-	0	5	-		+ve	0	23	-
	Hepatica americana	0	0	-	10	35	-		+ve	0	0	-
	Lycopodium lucidulum	0	0	0	0	0	0		0	3	0	0
	Mitchella repens	0	5	+ve	0	10	-		+ve	3	0	-
	Oryzopsis asperifolia	10	30	+200	80	70	240		-71	30	22	26

Appendix III.

Changes In Percent Frequency Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire.
A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An
Unlogged-Unburned Stand (Concl'd.)

Abundance ^{a/} Class (% Frequency June)	Species	Control			Logged			Logged-Burned				
		C ₁	C ₂	% seasonal ^{b/} change	L ₁	L ₂	Î ₂	% treatment ^{c/} (logging) change		% treatment ^{d/} (burning) change		
								B ₁	B ₂		Î ₂	
0-10	Pinus resinosa	0	0	0	0	0	0	0	3	0	-	-ve
	P. strobus	10	15	+50	15	15	22	-33	18	0	18	-100
	Populus tremuloides	10	0	-100	15	45	0	+ve	12	8	36	-78
	Pteridium aquilinum	5	35	+600	15	25	105	76	10	48	17	+188
	Rhus radicans	0	5	+ve	0	0	0	0	10	0	-	-ve
	Vaccinium angustifolium	0	10	+ve	20	30	-	+ve	22	5	31	-84
	V. myrtilloides	0	5	+ve	10	25	-	+ve	0	2	-	+ve
	Virburnum acerifolium	0	0	0	5	10	-	+ve	12	5	24	-79

^{a/} Species allotment to an abundance class is based on its frequency of occurrence in 20 quadrats (1/2 m x 1/2 m) in a June sample from an unlogged-unburned stand.

^{b/} % Seasonal change = $((C_2 - C_1) / C_1) \cdot 100$, where C₁, C₂ = % frequency of a species in June & August sample. June sample was before and August sample was after the application of stand treatment.

^{c/} % Change (logging) calculated using equation (IV), page 11.

^{d/} Changed (fire) calculated using equation (V), page 12.

Appendix IV. Changes In Biomass Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire. A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An Unlogged-Unburned Stand.

Abundance ^{a/} Class	Species	Control			Logged			Logged-Burned				
		C ₁	C ₂	% seasonal ^{b/} change	L ₁	L ₂	I ₂	% treatment ^{c/} (logging) change	B ₁	B ₂	% treatment ^{d/} (fire) change	
91-100 -		17.3	15.3	-12	31.3	15.5	27.7	-44	24.7	0.5	12.2	-96
81-90 -		13.1	22.6	+79	37.2	46.9	64.2	-27	17.2	1.5	21.7	-93
71-80	Maianthemum canadense	11.5	18.1	+57	5.9	31.5	9.3	+239	9.2	6.9	49.1	-86
61-70	Aralia nudicaulis											
	Aster macrophyllus											
51-60 -												
41-50	Gaultheria procumbens	1.8	0.4	-78	0.4	1.1	0.1	+1137	3.2	0.1	8.8	-99
	Trientalis borealis	0.5	0.6	+20	0.4	0.3	0.48	-37	0.2	0.0	0.15	-100
	Waldsteinia fragarioides	2.8	3.9	+39	0.1	0.0	0.1	-100	0.3	0.1	0.0	-ve
31-40	Cornus canadensis	3.7	3.1	-16	0.2	1.4	0.2	+735	2.2	0.3	15.4	-98
21-30	Corylus cornuta	6.3	2.4	-62	0.5	5.6	0.2	2840	7.7	5.6	86.2	-93

Appendix IV. Changes In Biomass Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire. A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An Unlogged-Unburned Stand. (Cont'd.)

Abundance ^{a/} Class	Species	Control					Logged					Logged-Burned				
		C ₁	C ₂	% seasonal ^{b/} change	L ₁	L ₂	Î ₂	% treatment ^{c/} (logging) change	B ₁	B ₂	Î ₂	% treatment ^{d/} (fire) change				
11-20	Carex sp.	0.7	1.4	+100	0.4	2.3	0.8	+188	2.5	2.0	14.4	-86				
	Linnaea borealis	2.2	0.4	-82	0.4	0.2	0.1	+175	0.1	0.0	0.05	-100				
	Lycopodium obscurum	8.1	4.8	-41	0.0	4.5	-	+ve	0.6	0.0	-	-ve				
	Viola sp.	0.0	0.2	+ve	0.2	0.1	0.4	-75	0.0	0.0	-	-				
0-10	Acer rubrum	0.9	0.0	-100	0.0	0.8	0.0	+ve	0.0	0.3	-	-				
	Aralia racemosa	0.0	0.0	0	0.0	0.0	0.0	-	0.0	0.8	0.0	+ve				
	Betula papyrifera	0.0	0.0	0	0.3	0.1	-	-ve	0.1	0.0	0.06	-100				
	Convolvulus spithameus	0.0	0.0	0	0.0	0.0	0.0	0	0.0	1.0	-	+ve				
	Geranium bicknellii	0.0	0.0	0	0.0	0.0	0.0	0	0.0	4.1	0.0	+ve				
	Hepatica americana	0.0	0.0	0	5.7	4.3	-	-ve	0.0	0.0	-	-				
	Lycopodium lucidulum	0.0	0.0	0	0.0	0.0	0.0	0	3.5	0.0	0.0	-ve				
	Mitchella repens	0.0	0.1	+ve	0.0	11.0	-	+ve	16.4	0.0	0.0	-ve				
	Oryzopsis asperifolia	2.0	1.8	-10	24.1	11.2	21.7	-484	9.7	0.6	4.5	-87				
	Pinus resinosa	0.0	0.0	0	0.0	0.0	0.0	0	4.1	0.0	0.0	-ve				

Appendix IV. Changes In Biomass Of Important Species Of Minor-Vegetation Due To Season, Logging And Fire. A Species Is Allotted To An Abundance Class According To Its % Frequency In June - Sample From An Unlogged-Unburned Stand (Concl'd.)

Abundance- Class	Species	Control				Logged				Logged-Burned			
		% seasonal- change		L ₁	L ₂	I ₂	% treatment- (logging) change		B ₁	B ₂	B ₂	% treatment- (fire) change	
		C ₁	C ₂										
0-10	P. strobus	0.1	0.3	+200	2.4	0.4	7.2	-94	2.6	0.0	0.4	-100	
	Populus tremuloides	0.2	0.0	-100	0.1	44.8	0.0	+ve	0.0	15.8	-	+ve	
	Pteridium aquilinum	5.8	15.9	+174	8.1	17.2	22.2	-22	9.1	53.5	19.3	+176	
	Rhus radicans	0.0	0.5	+ve	0.0	0.0	-	-	0.6	0.0	-	-ve	
	Vaccinium angustifolium	8.9	3.3	-63	4.2	4.5	1.6	+189	1.6	0.1	1.7	-94	
	V. myrtilloides	0.0	0.6	+ve	8.7	7.6	-	-ve	5.2	0.1	4.5	-98	
	Viburnum acerifolium	0.0	0.0	0.0	0.3	2.7	-	+ve	1.8	0.0	16.2	-100	

a/ Species allotment to an abundance class is based on its frequency of occurrence in 20 quadrats (1/2 m x 1/2 m) in June - sample from an unlogged-unburned stand.

b/ % Seasonal change = $((C_2-C_1)/C_1).100$, where C₁ = Biomass (g/5m²) in June, C₂ = Biomass in August, June and August samples were before and after the application of stand treatment.

c/ % Change (logging) calculated using equation (IV), page 11.

d/ % Change (fire) calculated using equation (V), page 12.

Appendix V. Percent Relative Frequency And Percent Relative Biomass Of Important Species In Unlogged-Unburned, Logged-Unburned, And Logged-Burned Stands

Species		% Relative Frequency			% Relative Biomass		
		UL-UB	L-UB	L-B	UL-UB	L-UB	L-B
Acer rubrum	June	0.97	0.93	0.68	1.02	0.01	0.03
	Aug.	0.00	1.19	2.09	0.00	0.00	0.29
Aralia nudicaulis	June	11.65	12.14	6.36	15.24	28.37	13.98
	Aug.	11.53	11.30	7.74	23.58	21.90	1.59
Aralia racemosa	June	0.00	0.00	0.00	0.00	0.00	0.00
	Aug.	0.00	0.00	2.71	0.00	0.00	0.83
Aster macrophyllus	June	12.62	10.28	12.50	13.39	4.50	7.48
	Aug.	12.50	8.93	7.74	18.90	14.70	7.40
Betula papyrifera	June	0.00	0.93	1.81	0.00	0.22	0.08
	Aug.	0.00	3.57	3.76	0.00	0.04	0.02
Carex sp.	June	3.88	3.73	7.27	0.80	0.30	2.00
	Aug.	2.88	3.57	12.97	1.47	1.08	2.13
Convolvulus spithameus	June	0.00	0.00	0.00	0.00	0.00	0.00
	Aug.	0.00	0.00	3.76	0.00	0.00	1.08
Cornus canadensis	June	6.79	1.86	1.13	4.28	0.17	1.79
	Aug.	4.80	3.57	1.46	3.27	0.67	0.32
Corylus cornuta	June	5.82	1.86	8.63	7.35	0.40	6.25
	Aug.	3.40	5.35	10.04	2.32	2.64	5.99
Gaultheria procumbens	June	8.73	3.73	10.22	2.10	0.31	2.62
	Aug.	3.84	10.12	3.55	0.37	0.52	0.10
Geranium bicknellii	June	0.00	0.00	0.00	0.00	0.00	0.00
	Aug.	0.00	0.59	4.81	0.00	<0.00	4.39
Hepatica americana	June	0.00	1.86	0.00	0.00	4.33	0.00
	Aug.	0.00	4.16	0.00	0.00	2.02	0.00
Linnaea borealis	June	3.88	5.60	2.27	2.51	0.32	0.12
	Aug.	2.88	1.78	0.00	0.38	0.10	0.00

Appendix V. Percent Relative Frequency And Percent Relative Biomass Of Important Species In Unlogged-Unburned, Logged-Unburned, And Logged-Burned Stands (Cont'd.)

Species		% Relative Frequency			% Relative Biomass		
		UL-UB	L-UB	L-B	UL-UB	L-UB	L-B
<i>Lycopodium lucidulum</i>	June	0.00	0.00	0.68	0.00	0.00	2.88
	Aug.	0.00	0.00	0.00	0.00	0.00	0.00
<i>Lycopodium obscurum</i>	June	2.91	0.00	2.27	9.45	0.00	0.46
	Aug.	0.96	2.38	0.00	5.02	2.10	0.00
<i>Maianthemum canadense</i>	June	15.53	16.82	14.31	20.17	23.87	20.07
	Aug.	18.26	11.90	17.78	15.96	7.22	0.52
<i>Mitchella repens</i>	June	0.00	0.00	0.68	0.00	0.00	13.34
	Aug.	0.96	1.19	0.00	0.11	5.11	0.00
<i>Oryzopsis asperifolia</i>	June	1.94	14.95	6.81	2.28	18.40	7.92
	Aug.	5.76	8.33	4.60	1.91	5.21	0.68
<i>Pinus resinosa</i>	June	0.00	0.00	0.68	0.00	0.00	3.33
	Aug.	0.00	0.00	0.00	0.00	0.00	0.00
<i>Pinus strobus</i>	June	1.94	2.80	4.09	0.16	1.86	2.13
	Aug.	2.88	1.78	0.00	0.32	0.21	0.00
<i>Populus tremuloides</i>	June	1.94	2.80	2.72	0.18	0.09	0.03
	Aug.	0.00	5.36	1.67	0.00	20.92	16.88
<i>Pteridium aquilinum</i>	June	0.97	2.80	2.27	6.73	6.19	7.41
	Aug.	6.73	2.98	10.04	16.64	8.03	57.21
<i>Rhus radicans</i>	June	0.00	0.00	2.27	0.00	0.00	0.52
	Aug.	0.06	0.00	0.00	0.54	0.00	0.00
<i>Trientalis borealis</i>	June	8.73	8.41	2.95	0.62	0.32	0.15
	Aug.	7.69	2.98	0.00	0.62	0.12	0.00
<i>Vaccinium angustifolium</i>	June	2.91	3.73	5.00	10.37	3.21	1.32
	Aug.	1.92	3.57	1.04	3.42	2.10	0.16
<i>Vaccinium myrtilloides</i>	June	0.00	1.86	0.00	0.00	6.63	0.00
	Aug.	0.96	2.98	0.41	0.62	3.55	0.16

Appendix V. Percent Relative Frequency And Percent Relative Biomass Of Important Species In Unlogged-Unburned, Logged-Unburned, And Logged-Burned Stands (Concl'd.)

Species		% Relative Frequency			% Relative Biomass		
		UL-UB	L-UB	L-B	UL-UB	L-UB	L-B
Viburnum acerifolium	June	0.00	0.93	2.72	0.00	0.15	1.49
	Aug.	0.00	1.19	1.04	0.00	1.26	0.03
Viola sp.	June	2.91	0.93	0.00	<0.00	0.07	0.00
	Aug.	2.88	1.19	2.09	0.20	0.04	<0.00
Waldsteinia fragarioides	June	8.73	0.93	1.59	3.26	<0.00	0.23
	Aug.	11.53	0.00	0.62	4.07	0.00	0.14

N.B. % Relative Frequency and Relative Biomass are based on values in Tables 5, p. 16-18.

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